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CLAIMS

1. A flash memory device, characterized by:

a silicon substrate,

a first electrode formed on said silicon substrate with an insulation film interposed therebetween, and

a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween,

said inter-electrode insulation film having a stacked structure including at least one silicon oxide film and one silicon nitride film, at least a part of said silicon oxide film containing Kr with a surface density of $10^{10}cm^{-2}$ or more.

2. A flash memory device as claimed in claim 1, characterized in that said first electrode includes a polysilicon film on a surface thereof, and wherein said inter-electrode insulation film has a stacked structure in which a first silicon nitride film, a first silicon oxide film, a second silicon nitride film and a second silicon oxide film are stacked consecutively.

3. A flash memory device as claimed in claim 1, characterized in that said first electrode includes a polysilicon film on a surface thereof, and wherein said inter-electrode insulation film is formed of three layers of a silicon oxide film, a silicon nitride film and a silicon oxide film.

4. A flash memory device as claimed in claim 1, characterized in that said first electrode includes a polysilicon film on a surface thereof, and wherein said inter-electrode film is formed of two layers of a first silicon nitride film and a second silicon oxide film.

5. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween, said inter-electrode insulation film having a stacked structure including therein at least one silicon oxide film and one silicon nitride film,

characterized in that said silicon oxide film is formed by a process comprising the steps of: supplying a gas containing oxygen and a gas

predominantly of Kr into a processing chamber, and exciting plasma in said processing chamber by a microwave.

6. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween, said inter-electrode insulation film having a stacked structure in which a first silicon nitride film, a first silicon oxide film, a second silicon nitride film and a second silicon oxide film are stacked consecutively, said first electrode having a polysilicon surface,

characterized in that said first and second silicon oxide films are formed by a process comprising the steps of: introducing a gas containing oxygen and a gas predominantly of Kr into a processing chamber, and exciting plasma in said processing chamber by a microwave.

7. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode formed on said silicon substrate with an insulation film interposed

therebetween, and a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween, said inter-electrode insulation film having a stacked structure in which a first silicon oxide film, a silicon nitride film and a second silicon oxide film are stacked consecutively, said first electrode having a polysilicon surface,

characterized in that said first and second silicon oxide films are formed by a process comprising the steps of: introducing a gas containing oxygen and a gas predominantly of Kr into a processing chamber, and exciting plasma in said processing chamber by a microwave.

8. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween, said inter-electrode insulation film having a two-layer structure in which a silicon oxide film and a silicon nitride film are stacked consecutively, said first electrode having a polysilicon surface,

characterized in that said silicon oxide film are formed by a process comprising the steps of: introducing a gas containing oxygen and a gas predominantly of Kr into a processing chamber, and exciting plasma in said processing chamber by a

microwave.

9. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween, said inter-electrode insulation film having a stacked structure including at least one silicon oxide film and at least one silicon nitride film,

characterized in that said silicon oxide film is formed by a process comprising the step of: exposing a silicon oxide film deposited by a CVD process to atomic state oxygen O* formed by microwave excitation of plasma in a mixed gas of an oxygen-containing gas and an inert gas predominantly of a Kr gas.

10. A fabrication process of a flash memory device, said flash memory device comprising a silicon substrate, a first electrode formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween, said inter-electrode

insulation film having a stacked structure in which a first silicon nitride film, a first silicon oxide film, a second silicon nitride film and a second silicon oxide film are stacked consecutively, said first electrode having a polysilicon surface,

characterized in that said first and second silicon oxide films are formed by a process comprising the step of: exposing a silicon oxide film deposited by a CVD process to atomic state oxygen O* formed by exciting plasma in a mixed gas of a gas containing oxygen and a gas predominantly of a Kr gas, by a microwave.

11. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween, said inter-electrode insulation film having a stacked structure in which a first silicon oxide film, a silicon nitride film and a second silicon oxide film are stacked consecutively, said first electrode having a polysilicon surface,

characterized in that said second silicon oxide film are formed by a process comprising the step of: exposing a silicon oxide film deposited by a CVD process to atomic state oxygen O* formed by exciting plasma in a mixed gas of a gas containing oxygen and a gas predominantly of a Kr gas by a

microwave.

12. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween, said inter-electrode insulation film having a stacked structure including at least one silicon oxide film and at least one silicon nitride film,

characterized in that said silicon nitride film are formed by a process comprising the steps of: introducing a gas containing any of an NH_3 gas or an N_2 gas and an H_2 gas and a gas predominantly of an Ar gas or a Kr gas into a processing chamber, and exciting plasma in said processing chamber by a microwave.

13. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween, said inter-electrode

insulation film having a stacked structure in which a first silicon nitride film, a first silicon oxide film, a second silicon nitride film and a second silicon oxide film are stacked consecutively, said first electrode having a polysilicon surface,

characterized in that said first and second silicon nitride films are formed by a process comprising the steps of: introducing an NH_3 gas or a gas containing N_2 and H_2 and a gas predominantly of an Ar gas or a Kr gas into a processing chamber, and exciting plasma in said processing chamber by a microwave.

14. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween, said inter-electrode insulation film having a stacked structure in which a first silicon oxide film, a silicon nitride film and a second silicon oxide film are stacked consecutively, said first electrode having a polysilicon surface,

characterized in that said silicon oxide film are formed by a process comprising the steps of: introducing an NH_3 gas or a gas containing N_2 and H_2 and a gas predominantly of an Ar gas or a Kr gas into a processing chamber, and exciting plasma in said processing chamber by a microwave.

15. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween, said inter-electrode insulation film having a two-layer structure in which a silicon oxide film and a silicon nitride film are stacked consecutively, said first electrode having a polysilicon surface,

characterized in that said silicon nitride film are formed by a process comprising the steps of: introducing an NH_3 gas or a gas containing N_2 and H_2 and a gas predominantly of an Ar gas or a Kr gas into a processing chamber, and exciting plasma in said processing chamber by a microwave.

16. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween, said inter-electrode insulation film having a stacked structure containing at least one silicon oxide film and at least one silicon nitride film,

characterized in that said silicon nitride film is formed by a process comprising the step of:

exposing a silicon nitride film deposited by a CVD process to hydrogen nitride radicals NH* formed by microwave excitation of plasma in a mixed gas of an NH_3 gas or a gas containing N_2 and H_2 and a gas predominantly of an Ar gas or a Kr gas.

17. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween, said inter-electrode insulation film having a stacked structure in which a first silicon nitride film, a first silicon oxide film, a second silicon nitride film and a second silicon oxide film are stacked consecutively, said first electrode having a polysilicon surface,

characterized in that each of said first and second silicon nitride films is formed by a process comprising the step of: exposing a silicon nitride film deposited by a CVD process to hydrogen nitride radicals NH* formed by exciting plasma in a mixed gas of an NH_3 gas or a gas containing N_2 and H_2 and a gas predominantly of an Ar gas or a Kr gas by a microwave.

18. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween, said first electrode having a polysilicon surface,

characterized in that said silicon nitride film is formed by a process comprising the step of: exposing a silicon nitride film deposited by a CVD process to hydrogen nitride radicals NH* formed by exciting plasma in a mixed gas of an NH_3 gas or a gas containing N_2 and H_2 and a gas predominantly of an Ar gas or a Kr gas by a microwave.

19. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode insulation film interposed therebetween, said inter-electrode insulation film having a two-layer structure in which a silicon oxide film and a silicon nitride film are stacked consecutively, said first electrode having a polysilicon surface,

characterized in that said inter-electrode insulation film is formed by a process comprising the step of: exposing a silicon nitride film deposited by

a CVD profess to hydrogen nitride radicals NH* formed by exciting plasma in a mixed gas of an NH_3 gas or a gas containing N_2 and H_2 and a gas predominantly of an Ar gas or a Kr gas by a microwave.

20. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode of polysilicon formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode oxide film interposed therebetween,

characterized in that said inter-electrode oxide film is formed by a process comprising the steps of:

depositing a polysilicon film on said silicon substrate as said first electrode; and

exposing a surface of said polysilicon film to atomic state oxygen O* formed by exciting plasma in a mixed gas of a gas containing oxygen and an inert gas predominantly of a Kr gas by a microwave.

21. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode of polysilicon formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode

formed on said first electrode with an inter-electrode nitride film,

characterized in that

said inter-electrode nitride film is formed by a process comprising the steps of:

depositing a polysilicon film on said silicon substrate as said first electrode; and

exposing a surface of said polysilicon film to hydrogen nitride radicals NH* formed by exciting plasma in a mixed gas of a gas containing nitrogen and hydrogen and an inert gas predominantly of a Kr gas by a microwave.

22. A method of fabricating a flash memory device, said flash memory device comprising a silicon substrate, a first electrode of polysilicon formed on said silicon substrate with an insulation film interposed therebetween, and a second electrode formed on said first electrode with an inter-electrode oxynitride film interposed therebetween,

characterized in that said inter-electrode oxynitride film being formed by a process comprising the steps of:

depositing a polysilicon film on said silicon substrate as said first electrode; and

converting a surface of said polysilicon film to a silicon oxynitride film by exposing said polysilicon film to plasma formed by exciting a mixed gas of an inert gas predominantly of Ar or Kr and a gas containing oxygen and nitrogen by a microwave.

23. A method of forming a silicon oxide film, characterized by the steps of:

depositing a polysilicon film on a substrate; and

forming a silicon oxide film on a surface of said polysilicon film by exposing the surface of said polysilicon film to atomic state oxygen O*, said atomic state oxygen O* being formed by exciting plasma in a mixed gas of a gas containing oxygen and an inert gas predominantly of a Kr gas by a microwave.

24. A method of forming a silicon oxide film as claimed in claim 23, characterized in that said mixed gas is a mixture of oxygen and an inert gas predominantly of a Kr gas with a mixing ratio of 3% for oxygen and 97% for the inert gas.

25. A method of forming a silicon oxide film as claimed in claim 23, characterized in that said plasma has an electron density of $10^{12}cm^{-3}$ or more on said surface of said polysilicon film.

26. A method of forming a silicon oxide film as claimed in claim 23, characterized in that

said plasma has a plasma potential of 10 V or less at said surface of said polysilicon film.

27. A method of forming a silicon nitride film, characterized by the steps of:

depositing a polysilicon film on a substrate; and

forming a nitride film on a surface of said polysilicon film by exposing the surface of said polysilicon film to hydrogen nitride radicals NH*, said hydrogen nitride radicals NH* being formed by plasma that is excited in a mixed gas of a gas containing nitrogen and hydrogen as constituent elements and an inert gas predominantly of an Ar gas or a Kr gas by a microwave.

28. A method of forming a silicon nitride film as claimed in claim 27, characterized in that said gas containing nitrogen and hydrogen is an NH_3 gas.

29. A method of forming a silicon nitride film as claimed in claim 27, characterized in that said mixed gas is a mixture of an NH_3 gas and an

inert gas predominantly of an Ar gas or a Kr gas with a mixing ration of 2% for said NH_3 gas and 98% for said inert gas.

30. A method of forming a silicon nitride film as claimed in claim 27, characterized in that said gas containing nitrogen and hydrogen is a mixed gas of an N_2 gas and an H_2 gas.

31. A method of forming a silicon nitride film as claimed in claim 27, characterized in that said plasma has an electron density of $10^{12}cm^{-3}$ or more at said surface of said polysilicon film.

32. A method of forming a silicon nitride film as claimed in claim 27, characterized in that said plasma has a plasma potential of 10 V or less at said surface of said polysilicon film.

33. A method of forming an oxynitride film, characterized by the steps of:

depositing a polysilicon film on a substrate; and

converting a surface of said polysilicon film to a silicon oxynitride film by exposing said polysilicon film to plasma formed by exciting a mixed gas of an inert gas predominantly of Ar or Kr and a gas containing oxygen as a constituent element and a gas containing nitrogen as a constituent element, by a microwave.

34. A method of forming a silicon oxynitride film as claimed in claim 33, characterized in that said gas containing nitrogen is an NH_3 gas.

35. A method of forming a silicon oxynitride film as claimed in claim 33, characterized in that said mixed gas is a mixture of an inert gas predominantly of Ar or Kr and an oxygen gas and an NH_3 gas with a mixing ratio of 96.5% for said inert gas and 3% for said oxygen gas and 0.5% for said NH_3 gas.

36. A method of forming a silicon oxynitride film as claimed in claim 33, characterized

in that said gas containing nitrogen is a mixed gas of an N_2 gas and an H_2 gas.

37. A method of forming a silicon oxynitride film as claimed in claim 33, characterized in that said plasma has an electron density of $10^{12}cm^{-3}$ or more at said surface of said polysilicon film.

38. A method of forming a silicon oxynitride film as claimed in claim 33, characterized in that said plasma has a plasma potential of 10V or less at said surface of said polysilicon film.

39. A method of forming a silicon oxide film on a polysilicon film, characterized by the steps of:

forming plasma containing therein atomic state oxygen O* in a processing vessel of a microwave processing apparatus, said microwave processing apparatus including, in addition to said processing vessel, a shower plate provided in a part of said processing vessel so as to extend parallel with a substrate to be processed, said shower place including a number of apertures for supplying a

plasma gas toward said substrate to be processed, and a microwave radiation antenna provided such that said microwave radiation antenna emits a microwave into said processing vessel through said shower plate, said plasma being formed by supplying an inert gas predominantly of Kr and a gas containing oxygen into said processing vessel via said shower plate, and by supplying a microwave into said processing vessel from said microwave radiation antenna through said shower plate; and

oxidizing, in said processing vessel, a surface of said polysilicon film formed on said substrate by said plasma, to form said silicon oxide film.

40. A method of forming a silicon oxide film as claimed in claim 39, characterized in that said plasma has an electron density of $10^{12}cm^{-3}$ or more at said surface of said polysilicon film.

41. A method of forming a silicon oxide film as claimed in claim 39, characterized in that said plasma has a plasma potential of 10V or less at said surface of said polysilicon film.

42. A method of forming a silicon nitride film on a polysilicon film, characterized by the steps of:

forming plasma containing therein hydrogen nitride radicals NH * in a processing vessel of a microwave processing apparatus, said microwave processing apparatus including, in addition to said processing vessel, a shower plate provided in a part of said processing vessel so as to extend parallel with a substrate to be processed, said shower place including a number of apertures for supplying a plasma gas toward said substrate to be processed, and a microwave radiation antenna provided such that said microwave radiation antenna emits a microwave into said processing vessel through said shower plate, said plasma being formed by supplying an inert gas predominantly of Ar or Kr and a gas containing nitrogen and hydrogen into said processing vessel via said shower plate, and by supplying a microwave into said processing vessel from said microwave radiation antenna through said shower plate; and

nitriding, in said processing vessel, a surface of said polysilicon film formed on said substrate by said plasma, to form said silicon nitride film.

43. A method of forming a silicon nitride film as claimed in claim 42, characterized in that said gas containing nitrogen and hydrogen is an NH_3 gas.

44. A method of forming a silicon nitride film as claimed in claim 42, characterized in that said gas containing nitrogen and hydrogen is a mixed gas of an N_2 gas and an H_2 gas.

45. A method of forming a silicon nitride film as claimed in claim 42, characterized in that said plasma has an electron density of $10^{12}cm^{-3}$ or more at said surface of said polysilicon film.

46. A method of forming a silicon nitride film as claimed in claim 42, characterized in that said plasma has a plasma potential of 10V or less at said surface of said polysilicon film.

47. A method of forming a silicon oxynitride film on a polysilicon film, characterized by the steps of:

forming plasma containing therein atomic state oxygen O* and hydrogen nitride radicals NH * in a processing vessel of a microwave processing apparatus, said microwave processing apparatus including, in addition to said processing vessel, a

shower plate provided in a part of said processing vessel so as to extend parallel with a substrate to be processed, said shower place including a number of apertures for supplying a plasma gas toward said substrate to be processed, and a microwave radiation antenna provided such that said microwave radiation antenna emits a microwave into said processing vessel through said shower plate, said plasma being formed by supplying an inert gas predominantly of Ar or Kr and a gas containing oxygen as a constituent element and a gas containing nitrogen as a constituent element into said processing vessel via said shower plate, and by supplying a microwave into said processing vessel from said microwave radiation antenna through said shower plate; and

oxynitriding, in said processing vessel, a surface of said polysilicon film formed on said substrate by said plasma, to form said silicon oxynitride film.

48. A method of forming a silicon oxynitride film as claimed in claim 47, characterized in that said gas containing nitrogen and hydrogen is an NH_3 gas.

49. A method of forming a silicon

oxynitride film as claimed in claim 47, characterized in that said gas containing nitrogen and hydrogen is a mixed gas of an N_2 gas and an H_2 gas.

50. A method of forming a silicon oxynitride film as claimed in claim 47, characterized in that said plasma has an electron density of $10^{12}cm^{-3}$ or more at said surface of said polysilicon film.

51. A method of forming a silicon oxynitride film as claimed in claim 42, characterized in that said plasma has a plasma potential of 10V or less at said surface of said polysilicon film.